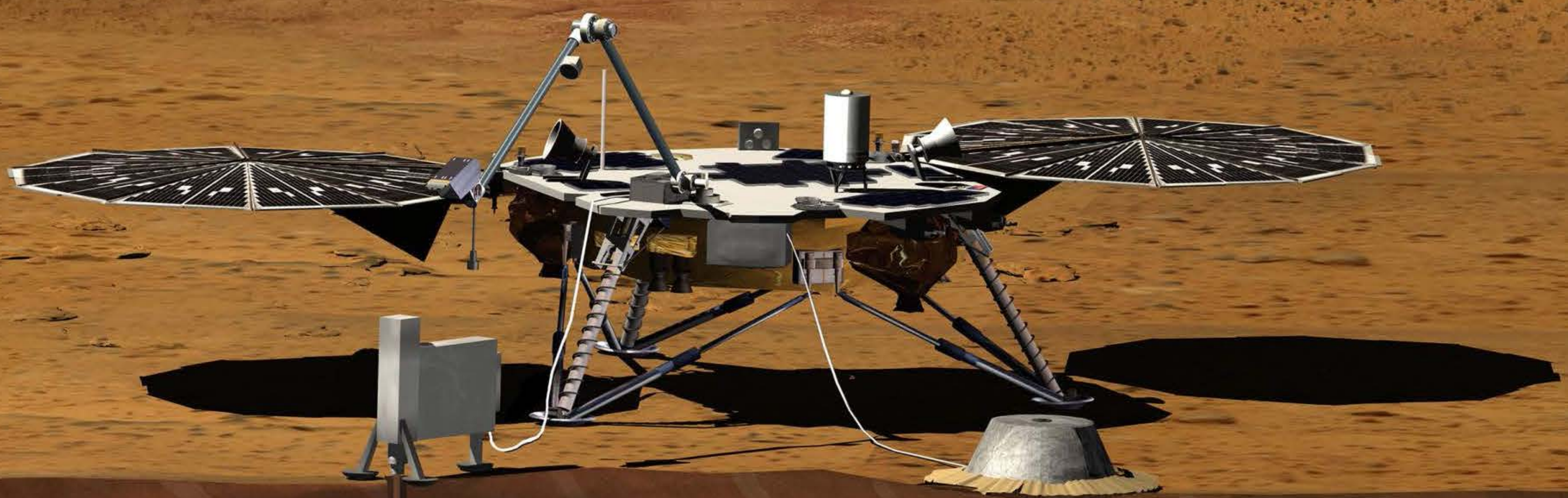
Overview of the InSight Entry, Descent, and Landing System



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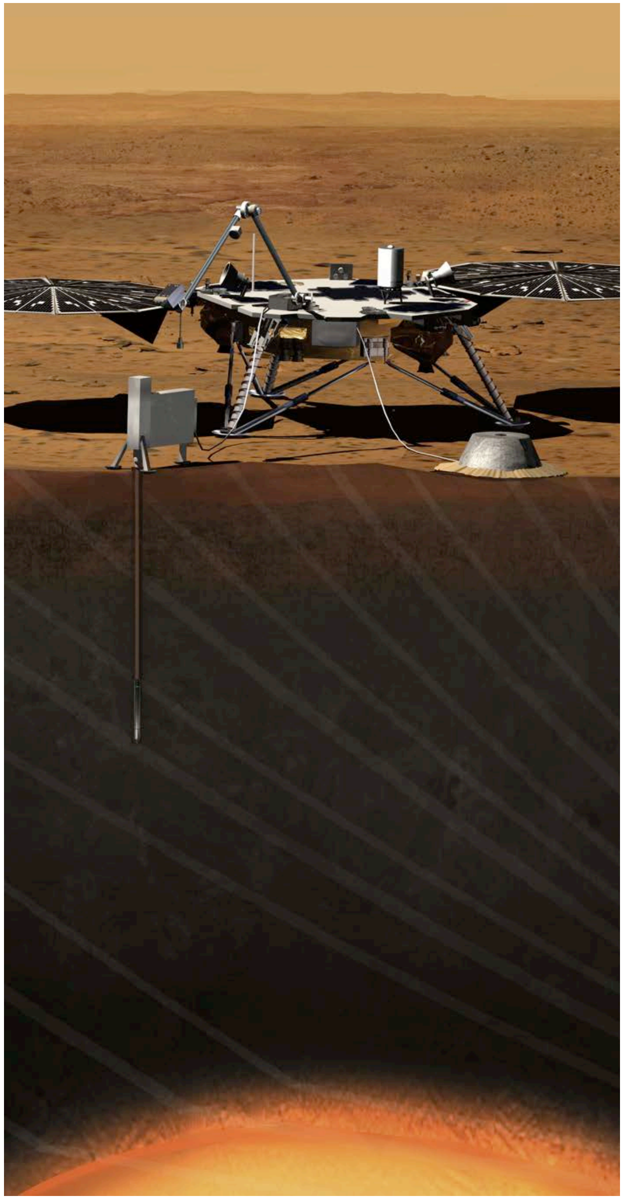
10th International Planetary Probe Workshop (IPPW)
June 17-21, 2013
San Jose, CA

Pre-Decisional Information – For Planning and Discussion Purposes Only

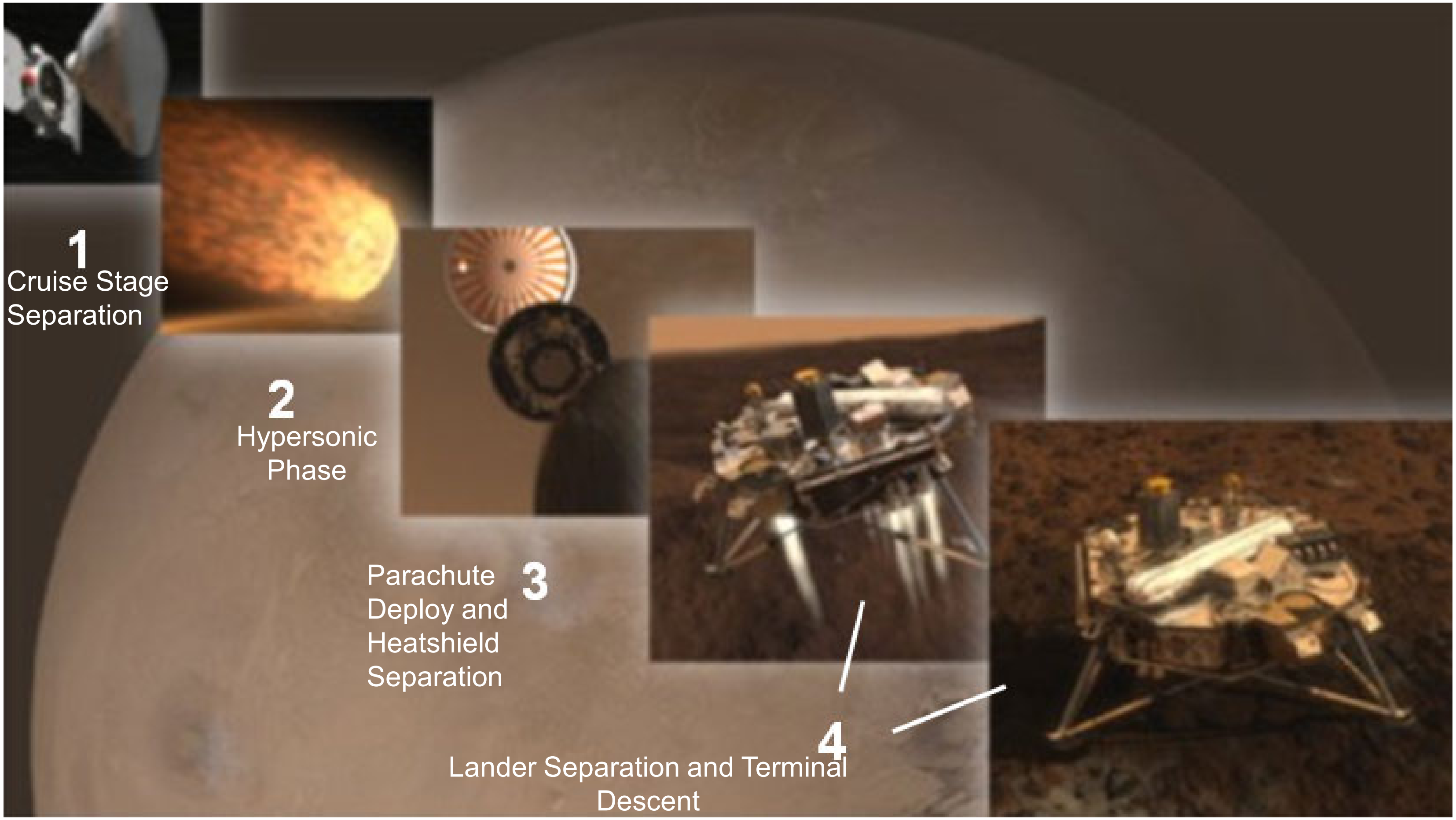
The InSight Discovery Class Mission



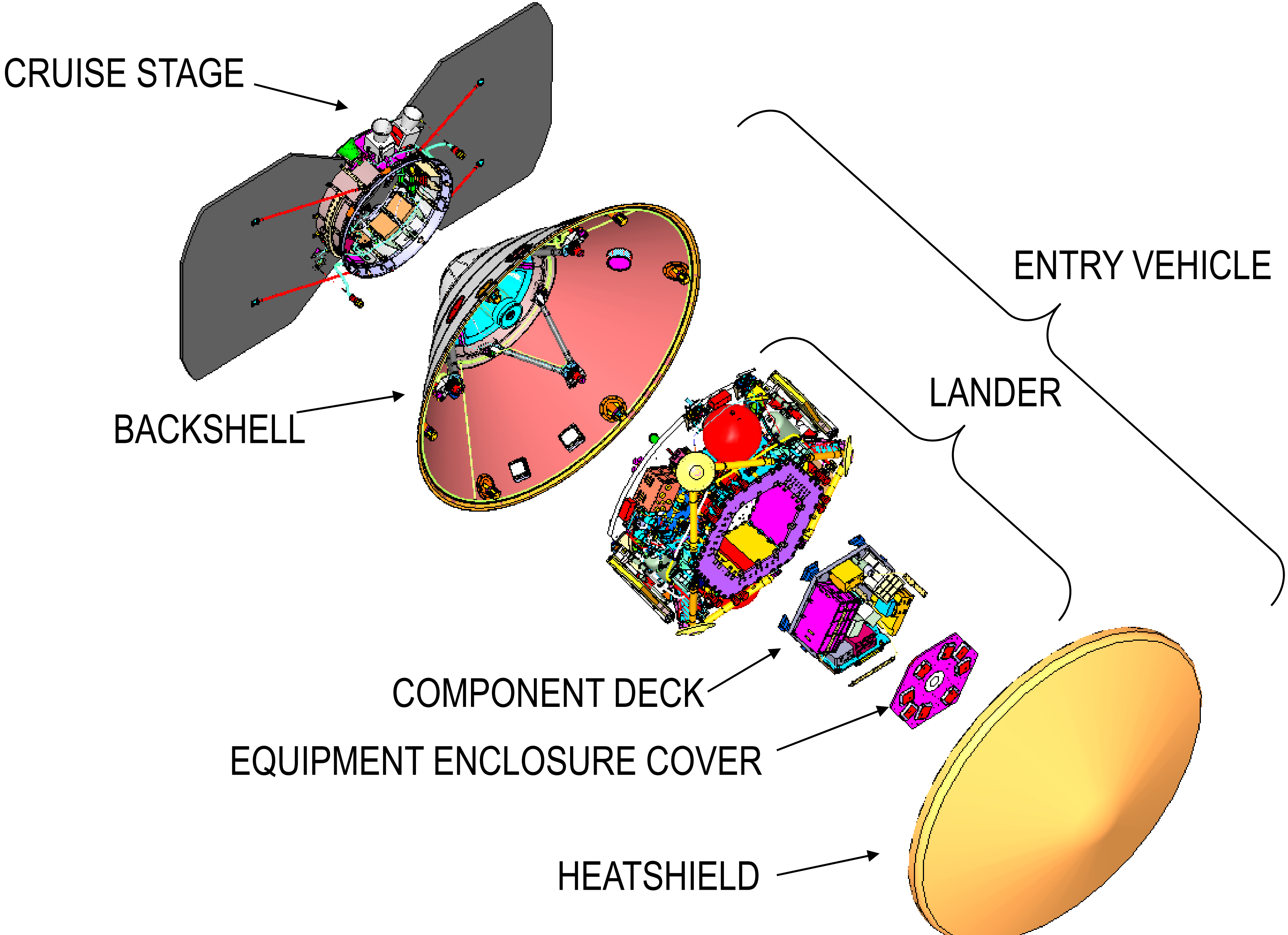
- Science Goals and Objectives
  - Understand the evolutionary formation of rocky planets by investigating the interior structure and processes of Mars
  - Investigate the dynamics of Martian tectonic activity and meteorite impacts
- Payload
  - Seismic Experiment for Interior Structure (SEIS), provided by CNES
  - Heat Flow and Physical Properties Package (HP3), provided by DLR
  - Rotation and Interior Structure Experiment (RISE), led by JPL
- Mission Details
  - Launch in March 2016
  - Land on September 20, 2016
  - Surface Operations: 700 sols

InSight Entry, Descent, and Landing Architecture

Leverages EDL architecture of the Phoenix mission



InSight Flight System



Pre-Decisional Information – For Planning and Discussion Purposes Only

Key Comparisons to Phoenix

	InSight	Phoenix
Launch Window	March 8-27, 2016	August 3-24, 2007
Arrival Date	September 20, 2016	May 25, 2008
Inertial Entry Velocity (km/s)	6.31	5.6
Max Landing Site Elevation	-2.5 km (wrt MOLA)	-4.1 km km (wrt MOLA)
Entry Mass (kg)	617.5 maximum	572.7
Ls / Dust Season	226° (Northern Autumn/Global Dust Storm Season)	76.7° (late Northern Hemisphere Spring)
Entry Flight Path Angle	-12.5 ± 0.26 degrees [3-sigma]	-13.0 ± 0.27 degrees [3-sigma]
Landing Site Latitude	5°N to 2°S	68°N
Surface Characteristics	Smooth, flat surface / broken up regolith	Sub-surface ice

InSight EDL Challenges

	InSight	Phoenix	Comments
Entry Velocity	6.3 km/s	5.6 km/s	InSight has to decelerate more than Phoenix did
Landing Site Altitude	−2.5 km	−4.1 km	InSight lands at a higher elevation—less time and atmosphere to decelerate
Entry Mass	617.5 kg*	572.7 kg	InSight has a higher ballistic coefficient—harder to slow down
Dust Storm Season	Global Dust Storm Season	N/A	InSight lands during Global Dust Storm Season—changes atmospheric density and causes heatshield TPS erosion

*Maximum possible value (MPV)

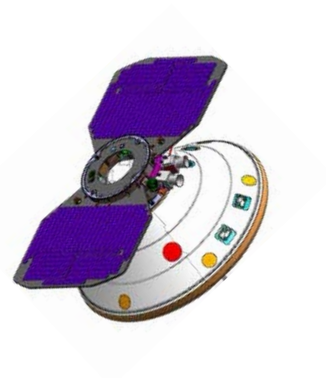
InSight has to decelerate more mass from a higher velocity and through less atmosphere than Phoenix

InSight EDL Overview

Pre-Entry Phase

DURATION: 3hrs

- X-band until C.S. Sep
- C.S. Sep E-7min
- Slew to Entry E-5min



Interface: Sensed Acc = 0.08 g

Hypersonic Phase

DURATION: 195 - 230 sec

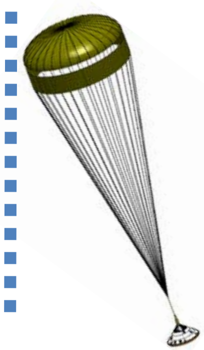
- EDL COMM UHF
- Radar On E+3min
- Thermal Battery E+4min
- Wait for Chute Trigger

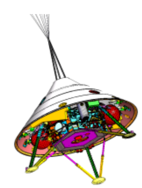
Interface: Sensed Acc, calc. vel (backup timer incl)

Parachute Phase

DURATION: 70 - 170 sec

- EDL COMM UHF
- H.S. Sep P+15sec
- Deploy Legs P+25sec
- Radar activated P+35sec
- Wait for B.S. Sep



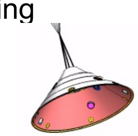


Interface: Nav computed alt/vel (max/min sep alt add robustness)

Powered Descent

DURATION: 40 - 50 sec

- EDL Comm Helix
- Tip-up LS+0.5sec
- TD Detect Object started LS+1sec
- Gravity Turn Pwrd Descent
- Constant vel for last 12 m
- TD detect responses Enabled on entering CV
- Radar vel down to 10 m
- Radar alt down to 1 m
- Wait for landing



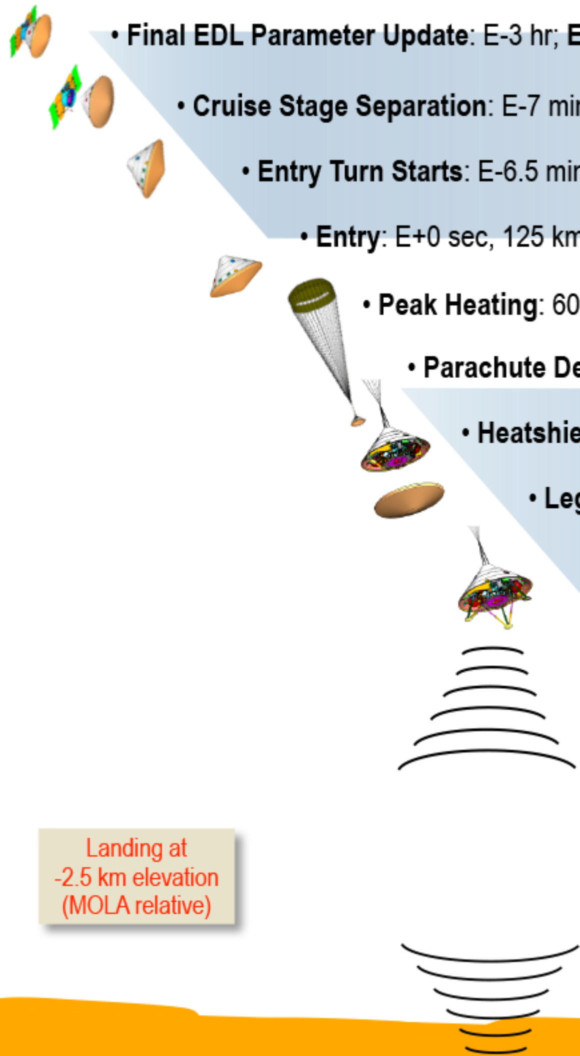
Surface

DURATION: 75 min

- Deploy solar arrays
- First comm with Earth verifying successful landing

* Sequence timing derived from Phoenix; Some adjustments will be required for InSight

InSight EDL Timeline



Entry Prep Phase

- **Final EDL Parameter Update**: E-3 hr; **Entry State Initialization**: E-10 min
- **Cruise Stage Separation**: E-7 min
- **Entry Turn Starts**: E-6.5 min; Turn completed by E-5 min
- **Entry**: E+0 sec, 125 km*, 6.3 km/s, EFPA = -12.5°

Hypersonic Phase

- **Peak Heating**: 60.2 W/cm^2, **Peak Deceleration**: 9.7 g
- **Parachute Deployment**: E+207 s, 10.0 km, Mach 1.56

Parachute Phase

- **Heatshield Jettison**: E+222 s, 87.2 km, 125 m/s
- **Leg Deployments**: E+232 s
- **Radar Activated**: E+242 s, T-122 s, 6.7 km
- **Radar First Acquisition**: T-62 s, 2.4 km

Terminal Descent Phase

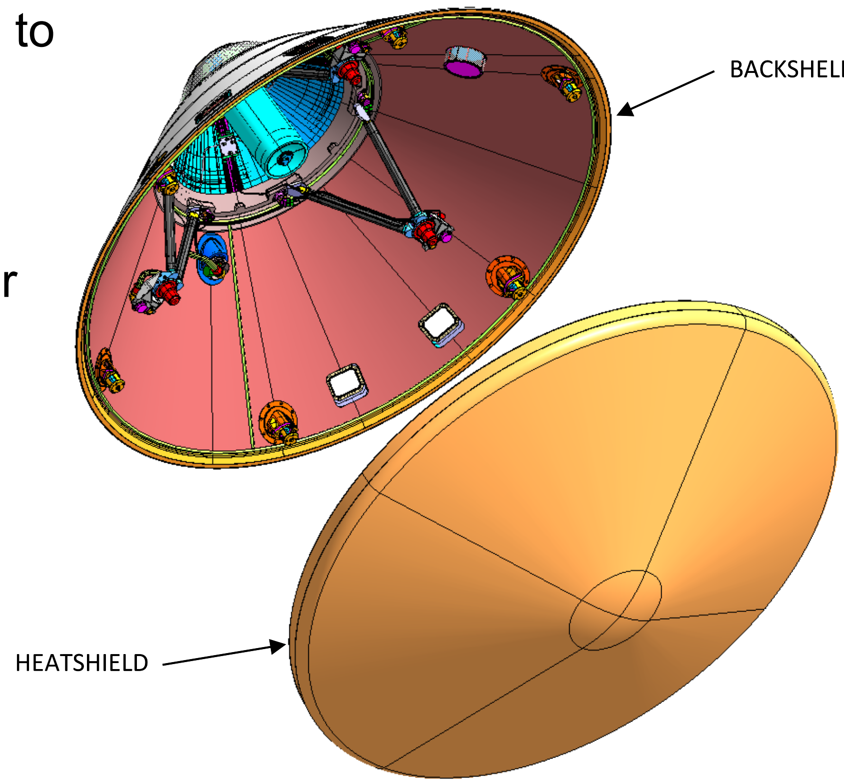
- **Lander Separation**: T-44 s, 1.23 km, 57.3 m/s
- **Gravity Turn Start**: T-41 s, 1.03 km
- **Constant Velocity Start**: T-15 s, 51 m, 7.5 m/s
- **Touchdown**: T-0 s, 0 m, V_v = 2.56 m/s, V_h = 0.25 m/s
- **Dust Settling**: T+0 to T+15 min

- **Begin Gyro-Compassing**: L+5 min
- **Solar Array Deploy**: L+16 min

*Entry altitude referenced to equatorial radius.
All other altitudes referenced to ground level

Hypersonic Phase

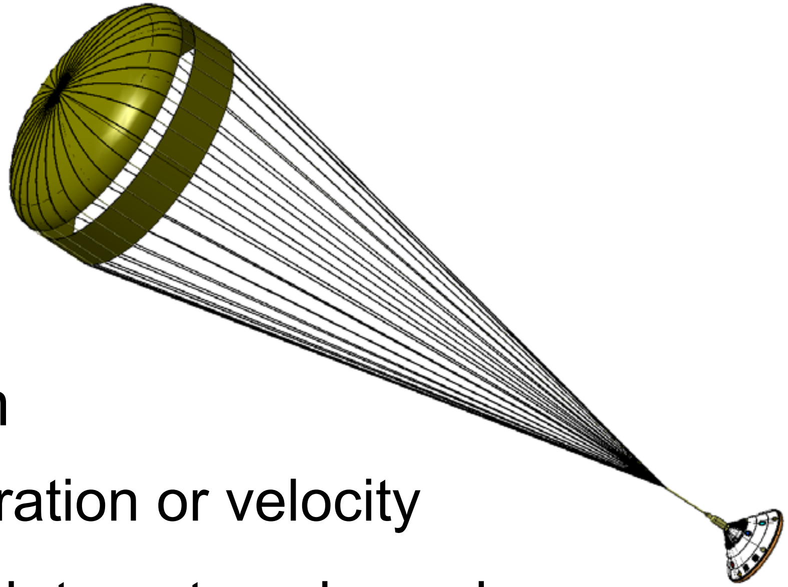
- Hypersonic phase spans from entry interface to parachute deployment
  - Dominated by aeroheating environment
- TPS materials and design approach from Phoenix are still valid and are the baseline for InSight
  - Slightly higher heating rate requirement than Phoenix and is within material capability
  - Plan to assess dust erosion of heatshield TPS
- Maintaining Phoenix approach to attitude control in this phase
  - Due to concerns over thruster-aero interaction, wide ACS deadbands to eliminate thruster firings (consistent with Phoenix)
    - "Safety net" deadbands still in place in the event attitude oscillations occur outside current worst estimates



2.65 m diameter, 70° half-cone geometry

Aeroshell Segment	TPS Type	Flight Heritage
Heatshield	SLA-561V	PHX, Pathfinder, MER
Backshell, lower	SLA-561S	PHX, Pathfinder, MER
Backshell, parachute cone	SLA-220	PHX, Viking, PAET, STS
Backshell, parachute cover	SLA-561V	PHX, Pathfinder, MER

Parachute Phase



- Build-to-print Phoenix parachute
  - 11.8 m, Viking-configuration DGB
  - Same mortar as Phoenix
- Phoenix parachute deploy algorithm
  - Hybrid trigger that uses either acceleration or velocity
  - Phoenix trigger set to 7.42 m/s^2, which targets a dynamic pressure of 490 Pa and Mach 1.65
  - Parameters will be retuned for InSight

Terminal Descent Phase

- Terminal descent is functionally identical to Phoenix
  - Final descent slowed by 12 pulse-mode hydrazine thrusters
  - Landing radar provides both altimeter and velocity data (via 4-beam Doppler)
  - Flight software guides vehicle along gravity turn trajectory
  - Touchdown ~ 365 sec after entry interface
    - Thrusters terminated when ground contact is sensed by touchdown sensors on any leg
    - Impacts ground ~ 2.3 m/s

Conclusions

- InSight EDL more challenged than Phoenix
  - Higher mass, higher entry velocity, higher landing altitude, and dust storm season
- Currently in Phase B
- Phoenix heritage allows for leverage of major test series
  - Hot fire test of propulsion system
  - Radar field test campaign
- Start of ATLO expected late 2014
- Launch March 2016, and landing on September 20, 2016